FOREST PEST MANAGEMENT
Pacific Southwest Region

SD11
A59R4
no 81-20

3430 Evaluation
August 31, 1981

ASSESSMENT OF OZONE INJURY TO PINES IN THE SOUTHERN SIERRA NEVADA, 1979/1980

Report No. 81-20

John Pronos, Plant Pathologist
Detlev R. Vogler, Plant Pathologist

ABSTRACT

Fifty-two ground plots containing ponderosa or Jeffrey pines were evaluated for changes in ozone injury between 1977 and 1980 on the Sierra and Sequoia National Forests. The general trend was one of increasing injury based on the amount of ozone symptoms present on pine foliage. Ambient ozone levels were monitored annually at one forest site beginning in 1976 and at a second site beginning in 1978. Although ozone standards were exceeded each year at both sites, seasonal ozone doses decreased during the monitoring periods, but still remained above the threshold for injury. We conclude that sensitive pines will continue to be injured and decline if ozone doses remain the same or increase in future years. There has been no mortality attributed to ozone in the trend plots, but some individual trees with symptoms and one year's needle retention may soon die, marking the start of ozone-related tree mortality in these forests. The Forest Pest Management Staff will continue its assessment of ozone injury in the Sierra Nevada.

USDA, FOREST SERVICE, PACIFIC SOUTHWEST REGION
State and Private Forestry, Forest Pest Management
630 Sansome Street, San Francisco, California 94111

INTRODUCTION

In 1977, the Forest Pest Management (FPM) Staff completed an extensive ground survey for ozone injury to pines within the Sierra and Sequoia National Forests. A network of injury trend plots was then established using ground sites and ratings from this survey. Trends in injury have been evaluated annually using chlorotic mottle symptoms present on pine foliage. Beginning in 1976, ambient ozone dosages have been monitored at selected sites in the Sierra Nevada. The results of these two activities were first summarized in 1978.1/ The objective of this report is to describe the status of air pollution impact during 1979 and 1980.

TRENDS IN OZONE INJURY

Fifty-two trend plots are scattered throughout the southern Sierra Nevada between 4000 and 8000 feet elevation. All plots were examined in 1977 and were subsequently divided into two groups. Each group was visited in alternate years. In each plot the foliage of ten ponderosa or Jeffrey pines was examined for chlorotic mottle and rated according to Table 1 below.

TABLE 1. Forest Pest Management Ozone Injury Scoring System for Pines.

INDIVIDUAL TREE SCORE	YOUNGEST NEEDLES WITH SYMPTOMS	AVERAGE PLOT SCORE	EXTENT OF INJURY
0	Current Year	0 - 0.9	Very Severe
1	Second Year	1.0 - 1.9	Severe
2	Third Year	2.0 - 2.9	Moderate
3	Fourth Year	3.0 - 3.9	Slight
4	None	4.0	No Symptoms

Results from each year's assessment were compared to the injury condition first found in 1977. Because the trend plots examined in 1979 and in 1980 were not the same, even though they represent the same geographical area, injury ratings for each year are compared in separate tables (Tables 2 and 3).

1/ Pronos, J., D.R. Vogler, and R.S. Smith, Jr. 1978. An evaluation of ozone injury to pines in the southern Sierra Nevada. U.S.D.A. Forest Service, Forest Insect and Disease Management Report 78-1. 17 p.

TABLE 2. Number of Injury Trend Plots by Rating Class in 1977 and 1979.

AVERAGE PLOT SCORE	RATING CLASS	RATING YEARS 1977	1979
0 - 0.9	Very Severe	0	0
1.0 - 1.9	Severe	0	6
2.0 - 2.9	Moderate	7	6
3.0 - 3.9	Slight	9	10
4.0	No Symptoms	11	5
	TOTAL:	27	27

TABLE 3. Number of Injury Trend Plots by Rating Class in 1977 and 1980.

AVERAGE PLOT SCORE	RATING CLASS	RATING YEARS 1977	1980
0 - 0.9	Very Severe	0	0
1.0 - 1.9	Severe	0	3
2.0 - 2.9	Moderate	4	3
3.0 - 3.9	Slight	11	13
4.0	No Symptoms	10	6
	TOTAL:	25	25

The overall trend in 1979 and 1980 was one of increasing ozone injury. Tables 2 and 3 show a definite shift to fewer plots with no symptoms and more plots with severe symptoms. In 1977 there were no plots with severe ratings as contrasted with six in 1979 and three in 1980. Similarly, 1979 and 1980 results showed about 50 percent fewer plots with no injury symptoms in comparison to 1977.

Another way to demonstrate trends is to summarize how individual plot scores changed between 1977 and 1979 or 1980 (Table 4). In both 1979 and 1980 most plots showed increased air pollution injury as judged by foliar symptoms. A paired t-test was used to statistically examine these 2- and 3-year changes. About one-half of the increased injury scores were significantly different at the 95% probability level.

TABLE 4. Changes in Ozone Injury between 1977 and 1979/80 Trend Plots.

STATUS OF INJURY	NUMBER OF PLOTS 1979	1980
Increased Injury	19 (7)[1/]	14 (6)
No Change	6	6
Decreased Injury	2 (0)	5 (0)
TOTAL:	27	25

1/ Figures in parentheses indicate the number of plots where injury ratings were significantly different at P = 0.05.

In 1977, plots with the greatest injury were located along the front range slopes adjacent to the San Joaquin Valley, and farther into the Sierra along major river drainages. The situation was similar in 1979 and 1980, but with increased symptoms of injury at most of these same sites. Figures 1 and 2 show the locations and ratings of all trend plots in the Sierra and Sequoia National Forests. One area with a high concentration of severe injury-rated plots was in the northwest corner of the Sequoia National Forest in the vicinity of Mountain Home Demonstration State Forest (Figure 2).

Only 11 of the 52 trend plots in 1979/80 had no ozone injury symptoms. Most of these plots were at or above 6000 feet elevation and were the farthest from the San Joaquin Valley. Table 5 shows the current distribution of plot ratings by elevation.

TABLE 5. Number of Trend Plots by Rating and Elevation, 1979/80.

ELEVATION	INJURY RATING SEVERE	MODERATE	SLIGHT	NO SYMPTOMS
4000	2	2	4	1
5000	6	3	2	1
6000	1	3	8	3
7000	0	1	7	3
8000	0	0	2	3
TOTAL:	9	9	23	11

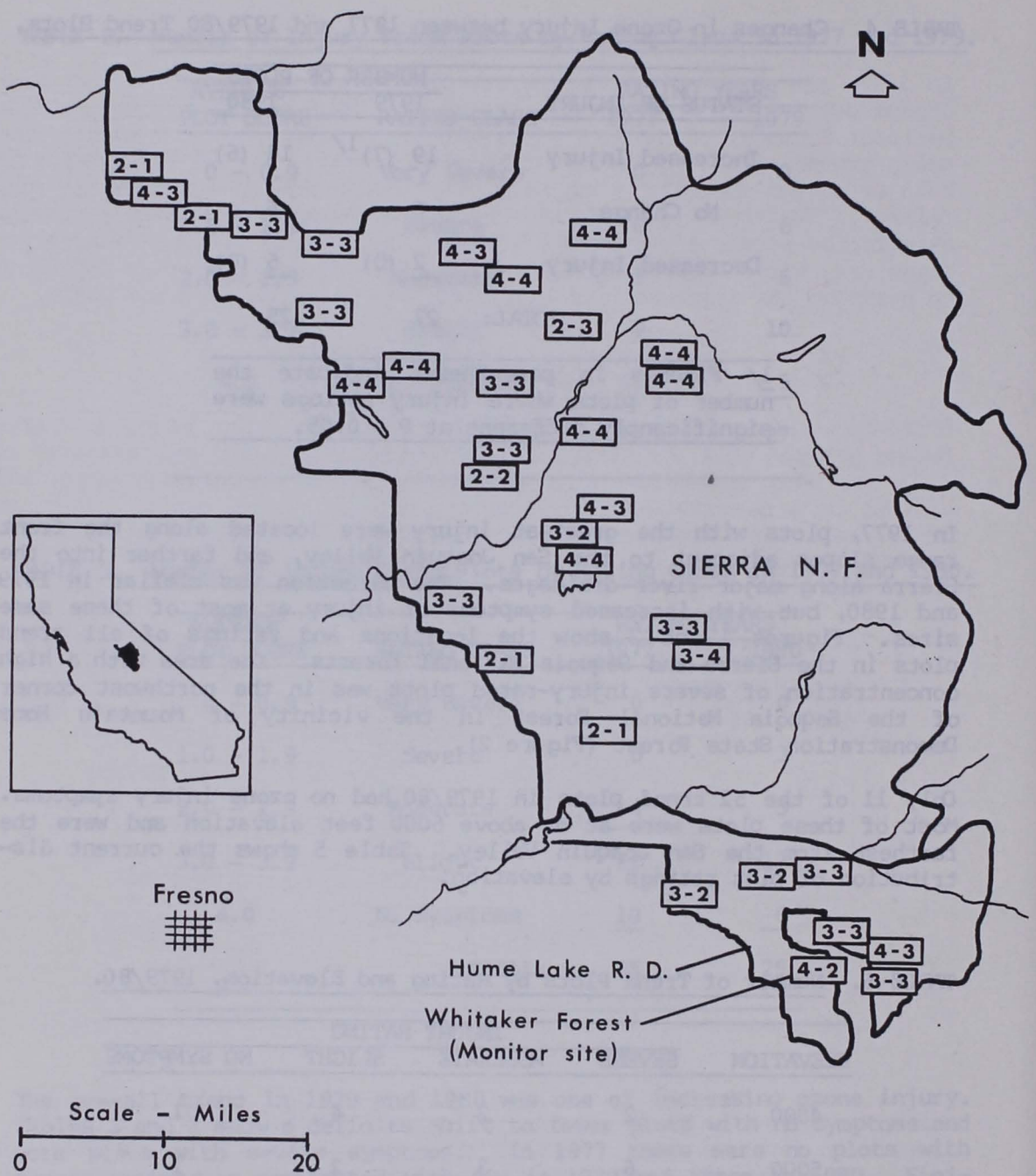


FIGURE 1. Locations and Scores of Ozone Injury Trend Plots on the Sierra National Forest and Hume Lake Ranger District, Sequoia National Forest. The left-hand number is the ozone rating in 1977, and the right-hand number is the 1979/80 rating: 4 = no symptoms; 3 = slight injury; 2 = moderate injury; 1 = severe injury.

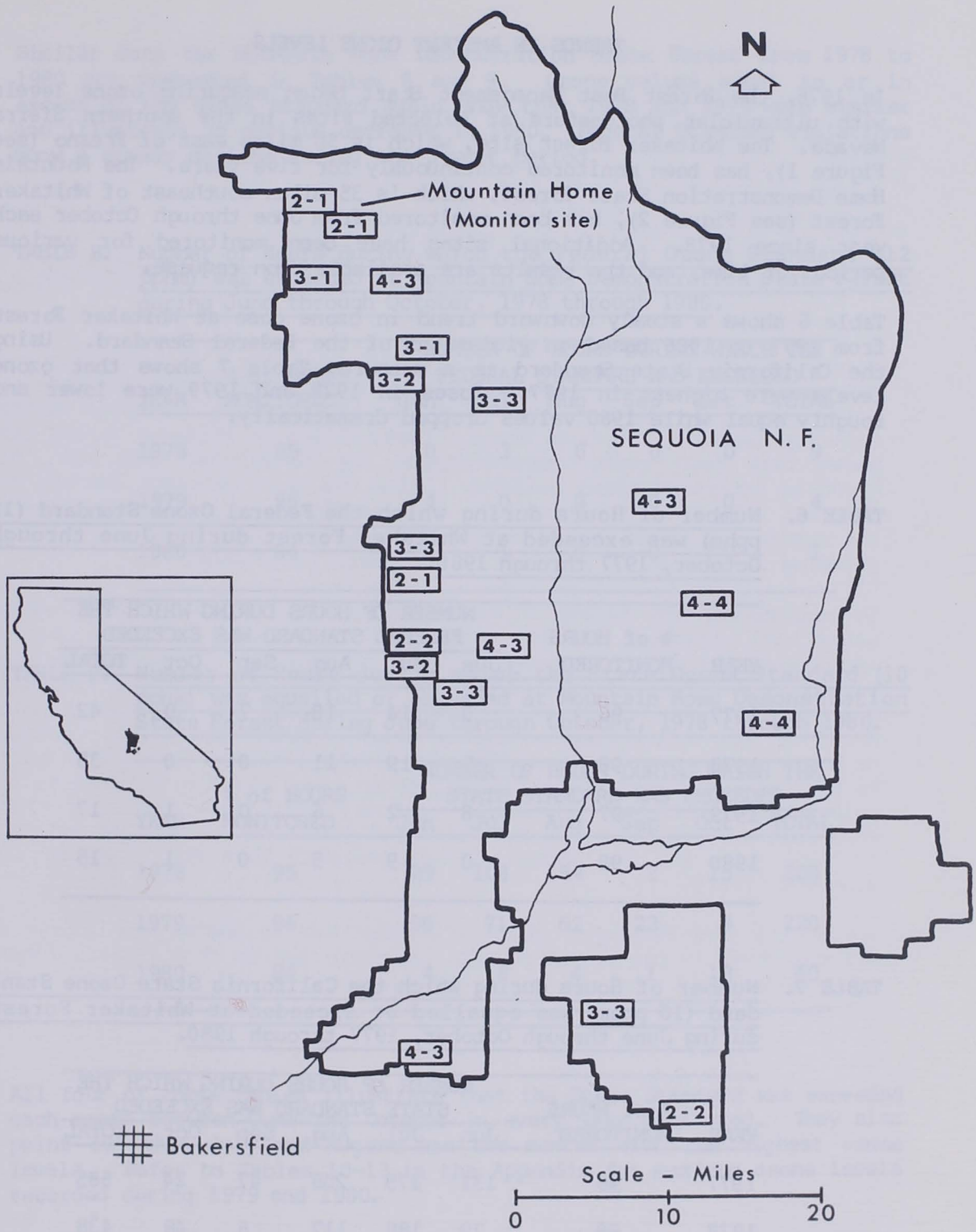


FIGURE 2. Locations and Scores of Ozone Injury Trend Plots on the Sequoia National Forest. The left-hand number is the ozone rating in 1977, and the right-hand number is the 1979/80 rating: 4 = no symptoms; 3 = slight injury; 2 = moderate injury; 1 = severe injury.

TRENDS IN AMBIENT OZONE LEVELS

In 1976, the Forest Pest Management Staff began measuring ozone levels with ultraviolet photometers at selected sites in the southern Sierra Nevada. The Whitaker Forest site, which is 50 miles east of Fresno (see Figure 1), has been monitored continuously for five years. The Mountain Home Demonstration State Forest, which is 35 miles southeast of Whitaker Forest (see Figure 2), has been monitored from June through October each year since 1978. Additional sites have been monitored for various periods of time, and the results are available upon request.

Table 6 shows a steady downward trend in ozone dose at Whitaker Forest from 1977 to 1980 based on violations of the Federal Standard. Using the California State Standard as a measure, Table 7 shows that ozone levels were highest in 1977. Doses in 1978 and 1979 were lower and roughly equal while 1980 values dropped dramatically.

TABLE 6. Number of Hours during which the Federal Ozone Standard (12 pphm) was exceeded at Whitaker Forest during June through October, 1977 through 1980.

YEAR	% of HOURS MONITORED	NUMBER OF HOURS DURING WHICH THE FEDERAL STANDARD WAS EXCEEDED					
		Jun	Jul	Aug	Sep	Oct	TOTAL
1977	96	3	14	18	7	0	42
1978	98	5	19	11	0	0	35
1979	97	8	2	6	0	1	17
1980	98	0	9	5	0	1	15

TABLE 7. Number of Hours during which the California State Ozone Standard (10 pphm) was equalled or exceeded at Whitaker Forest during June through October, 1977 through 1980.

YEAR	% of HOURS MONITORED	NUMBER OF HOURS DURING WHICH THE STATE STANDARD WAS EXCEEDED					
		Jun	Jul	Aug	Sep	Oct	TOTAL
1977	96	131	175	208	47	24	585
1978	98	79	188	117	6	48	438
1979	97	114	92	133	50	25	414
1980	98	22	82	103	16	23	246

Similar data for Mountain Home Demonstration State Forest from 1978 to 1980 are presented in Tables 8 and 9. Ozone values equal to or in excess of the State Standard again show that 1978 and 1979 were similar and illustrate an obvious decrease in 1980. Federal Standard violations show a steady decline during the 3-year period.

TABLE 8. Number of Hours during which the Federal Ozone Standard (12 pphm) was exceeded at Mountain Home Demonstration State Forest during June through October, 1978 through 1980.

YEAR	% of HOURS MONITORED	NUMBER OF HOURS DURING WHICH THE FEDERAL STANDARD WAS EXCEEDED					
		Jun	Jul	Aug	Sep	Oct	TOTAL
1978	95	0	3	6	0	0	9
1979	96	4	0	0	0	0	4
1980	84	0	1	0	0	0	1

TABLE 9. Number of Hours during which the State Ozone Standard (10 pphm) was equalled or exceeded at Mountain Home Demonstration State Forest during June through October, 1978 through 1980.

YEAR	% of HOURS MONITORED	NUMBER OF HOURS DURING WHICH THE STATE STANDARD WAS EXCEEDED					
		Jun	Jul	Aug	Sep	Oct	TOTAL
1978	95	29	108	54	2	15	208
1979	96	56	71	62	22	9	220
1980	84	4	18	4	1	13	40

All four of these tables illustrate that the State Standard was exceeded each month between June and October in every year monitored. They also point out that July and August are the months with the highest ozone levels. Refer to Tables 10-13 in the Appendix for maximum ozone levels recorded during 1979 and 1980.

DISCUSSION AND CONCLUSIONS

The amount of ozone injury symptoms on pines in trend plots has steadily increased between 1977 and 1980. The increased injury seen in 1979 was, at least partially, attributed to effects of a drought between 1975 and 1977. Reduced needle retention from drought stress could produce more severe injury scores using our rating system. Therefore, we expected some remission of symptoms in 1980 as trees continued to recover from moisture stress. No obvious remission was observed. Most chlorotic mottle present was caused by several years of exposure to ozone, and so it may not be possible to detect foliar responses to single-year changes in climate or ozone dose.

Trends in annual ozone dose are difficult to assess. Although the number of hours exceeding the standards decreased at Whitaker and Mountain Home after 1977, too few years have been monitored to determine whether this represents a long-term trend. Observations at Whitaker Forest have shown that high ozone concentrations are associated with hot, dry weather; afternoon cloud build-up limits the rise in ozone levels, and rainfall effectively reduces the concentration to background levels. The decline in ozone dose through 1980 may have been caused by weather patterns as much as by a reduction in source pollutants.

In conclusion, the amount of ozone injury on pine foliage at selected sites has increased annually since 1977 while the concentrations of ozone measured have decreased. This relationship suggests that the threshold level for ozone injury to pine foliage is lower than the State and Federal pollution standards used to summarize our monitoring data. Based on this information we assume that sensitive pines will continue to be injured as ozone moves into the southern Sierra Nevada each year. As yet there has been no tree mortality in trend plots attributed to air pollution. There are currently, however, individual declining trees with only one year's needle retention and chlorotic mottle that may soon die and mark the beginning of ozone-related tree mortality in the southern Sierra.

The Forest Pest Managment Staff will continue to assess the impact of air pollution in the Sierra Nevada. As described in this report, future assessments will include trend plot evaluation and ozone dose monitoring.

APPENDIX

Tables 10-13 illustrate the maximum hourly average ozone levels and the means of daily maxima for each month monitored at Whitaker Forest and at Mountain Home Demonstration State Forest in 1979 and 1980. The maximum hourly average is the highest one-hour average ozone reading during each month; the mean of daily maxima is the monthly mean of each day's maximum hourly average. These tables are useful in comparing ozone readings at the mountain sites with similar data in the San Joaquin Valley and elsewhere.

TABLE 10. Annual Summary of Ozone Monitoring at Whitaker Forest in 1979.

MONTH	HOURS MONITORED (Percent)	MAXIMUM HOURLY AVERAGE VALUE (Pphm)	MAXIMUM HOURLY AVERAGE FREQUENCY (Hours)	MEAN of DAILY MAXIMA (Pphm)	FREQUENCIES OF HOURLY AVERAGES EXCEEDING ESTABLISHED STANDARDS STATE [10 Pphm] (Hours)	STATE [10 Pphm] (Days)	FEDERAL [12 Pphm] (Hours)	FEDERAL [12 Pphm] (Days)
JANUARY	98	5	2	4	0	0	0	0
FEBRUARY	66	6	1	5	0	0	0	0
MARCH	0	--	--	--	--	--	--	--
APRIL	57	9	6	6	0	0	0	0
MAY	99	12	1	8	32	9	0	0
JUNE	99	14	2	10	114	22	8	4
JULY	93	13	2	10	92	18	2	1
AUGUST	96	13	6	10	133	18	6	4
SEPTEMBER	97	12	3	9	50	15	0	0
OCTOBER	99	13	1	7	25	6	1	1
NOVEMBER	98	6	4	4	0	0	0	0
DECEMBER	88	6	1	4	0	0	0	0

TABLE 11. Annual Summary of Ozone Monitoring at Whitaker Forest in 1980.

MONTH	HOURS MONITORED (Percent)	MAXIMUM HOURLY AVERAGE VALUE (Pphm)	MAXIMUM HOURLY AVERAGE FREQUENCY (Hours)	MEAN of DAILY MAXIMA (Pphm)	FREQUENCIES OF HOURLY AVERAGES EXCEEDING ESTABLISHED STANDARDS STATE [10 Pphm] (Hours)	STATE [10 Pphm] (Days)	FEDERAL [12 Pphm] (Hours)	FEDERAL [12 Pphm] (Days)
JANUARY	58	7	1	4	0	0	0	0
FEBRUARY	79	7	1	4	0	0	0	0
MARCH	50	7	1	6	0	0	0	0
APRIL	56	10	3	6	3	1	0	0
MAY	75	10	2	6	2	2	0	0
JUNE	100	11	8	8	22	6	0	0
JULY	98	14	5	10	82	21	9	3
AUGUST	99	13	5	10	103	21	5	3
SEPTEMBER	93	11	4	8	16	7	0	0
OCTOBER	97	13	1	7	23	7	1	1
NOVEMBER	100	10	5	6	5	3	0	0
DECEMBER	99	7	1	4	0	0	0	0

TABLE 12. Annual Summary of Ozone Monitoring at Mountain Home Demonstration State Forest in 1979.

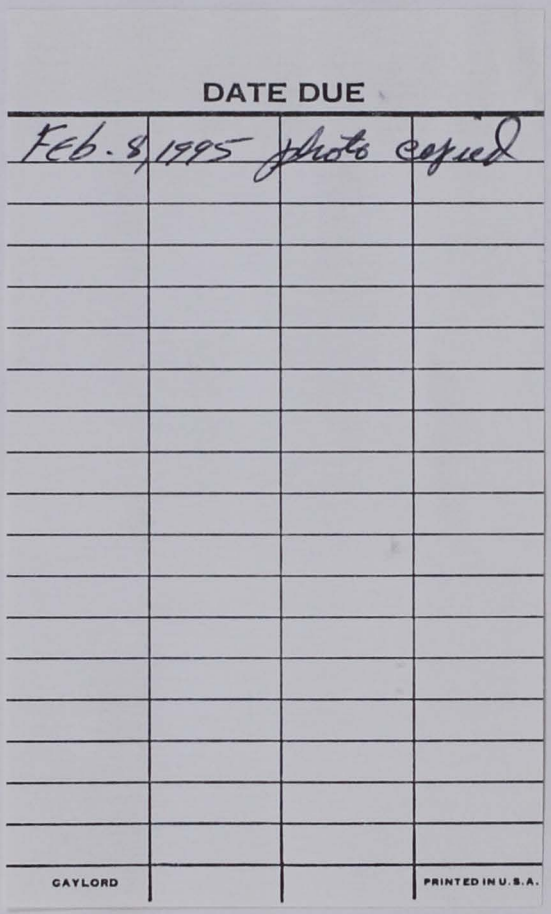
MONTH	HOURS MONITORED (Percent)	MAXIMUM HOURLY AVERAGE VALUE (Pphm)	MAXIMUM HOURLY AVERAGE FREQUENCY (Hours)	MEAN of DAILY MAXIMA (Pphm)	FREQUENCIES OF HOURLY AVERAGES EXCEEDING ESTABLISHED STANDARDS STATE [10 Pphm] (Hours)	STATE [10 Pphm] (Days)	FEDERAL [12 Pphm] (Hours)	FEDERAL [12 Pphm] (Days)
JUNE	83	13	4	10	56	14	4	1
JULY	100	12	4	10	71	18	0	0
AUGUST	98	12	5	9	62	12	0	0
SEPTEMBER	100	12	2	8	22	9	0	0
OCTOBER	100	11	4	6	9	4	0	0
NOVEMBER	15	6	1	4	0	0	0	0

TABLE 13. Annual Summary of Ozone Monitoring at Mountain Home Demonstration State Forest in 1980.

MONTH	HOURS MONITORED (Percent)	MAXIMUM HOURLY AVERAGE VALUE (Pphm)	MAXIMUM HOURLY AVERAGE FREQUENCY (Hours)	MEAN of DAILY MAXIMA (Pphm)	FREQUENCIES OF HOURLY AVERAGES EXCEEDING ESTABLISHED STANDARDS STATE [10 Pphm] (Hours)	STATE [10 Pphm] (Days)	FEDERAL [12 Pphm] (Hours)	FEDERAL [12 Pphm] (Days)
JUNE	58	10	4	8	4	3	0	0
JULY	91	13	1	8	18	6	1	1
AUGUST	99	11	1	8	4	2	0	0
SEPTEMBER	99	10	1	6	1	1	0	0
OCTOBER	72	12	3	7	13	7	0	0
NOVEMBER	46	8	2	5	0	0	0	0

LIBRARY U.S. FOREST SERVICE BERKELEY

STATION LIBRARY COPY



LIBRARY U.S. FOREST SERVICE BERKELEY

STATION LIBRARY COPY